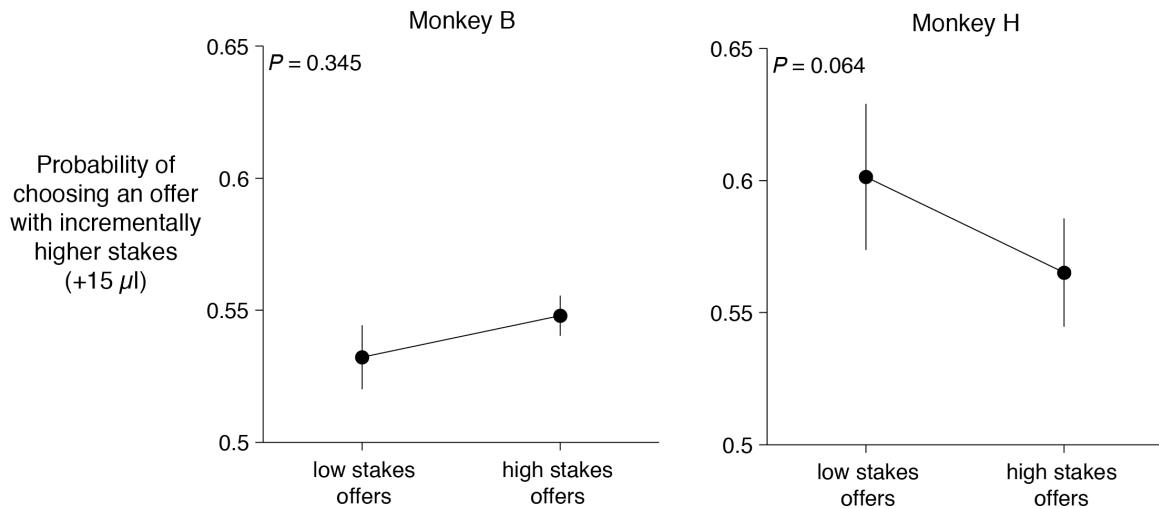


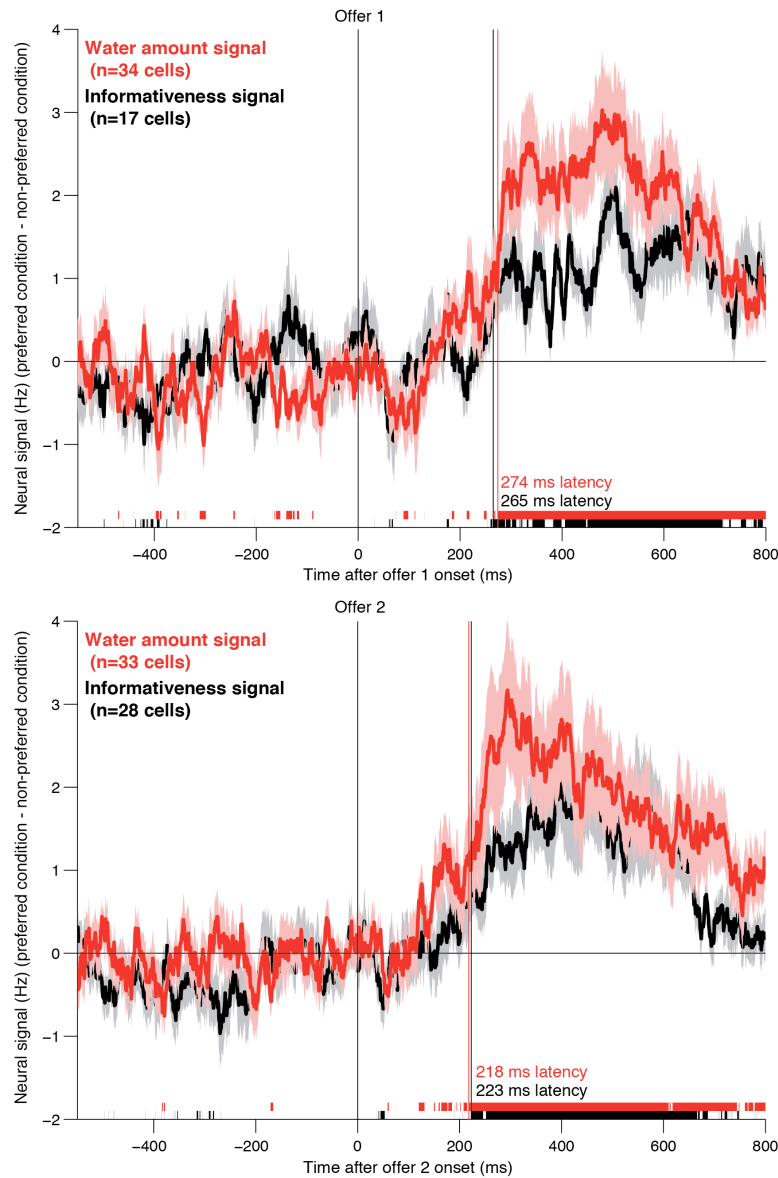
***Figure S1, related to Figure 1. Recording location in each of the two monkeys.***

We confirmed recording location before each recording session using our Brainsight system with structural magnetic resonance images taken before the experiment. Neuroimaging was performed at the Rochester Center for Brain Imaging, on a Siemens 3T MAGNETOM Trio Tim using 0.5 mm voxels. We confirmed recording locations by listening for characteristic sounds of white and gray matter during recording, which in all

cases matched the loci indicated by the Brainsight system with an error of  $<1$  mm in the horizontal plane and  $<2$  mm in the z-direction.



**Figure S2, related to Figure 2. Stakes has no significant effect on marginal value of water.** Animals valued information more highly for options with higher water amounts. This could be due to either an increasing value of information, or a decreasing marginal value of water (e.g. a convex utility function for water). To test between these alternatives, we measured how stakes affected the animal's behavioral sensitivity to water. We analyzed trials where the water amounts of the two offers differed by the smallest increment, 15ul of water. On these trials animals chose the larger water amount with 55.6% probability. Furthermore, this measure of behavioral sensitivity to water was similar for offer pairs with low stakes (75-210 µL; choice percent =  $55.6 \pm 1.5\%$ ) and high stakes (225-360 µL; choice percent =  $55.6 \pm 0.8\%$ ). Similar results were found in both monkeys (subject B choice percent: 53% for low stakes, 55% for high stakes,  $P=0.35$ , rank-sum test; subject H choice percent: 60% for low stakes, 57% for high stakes,  $P=0.06$ , rank-sum test). This suggests that the stakes had little effect on the marginal value of water, and hence that the cause of the animal's increased information seeking was a true increase in the value of information.



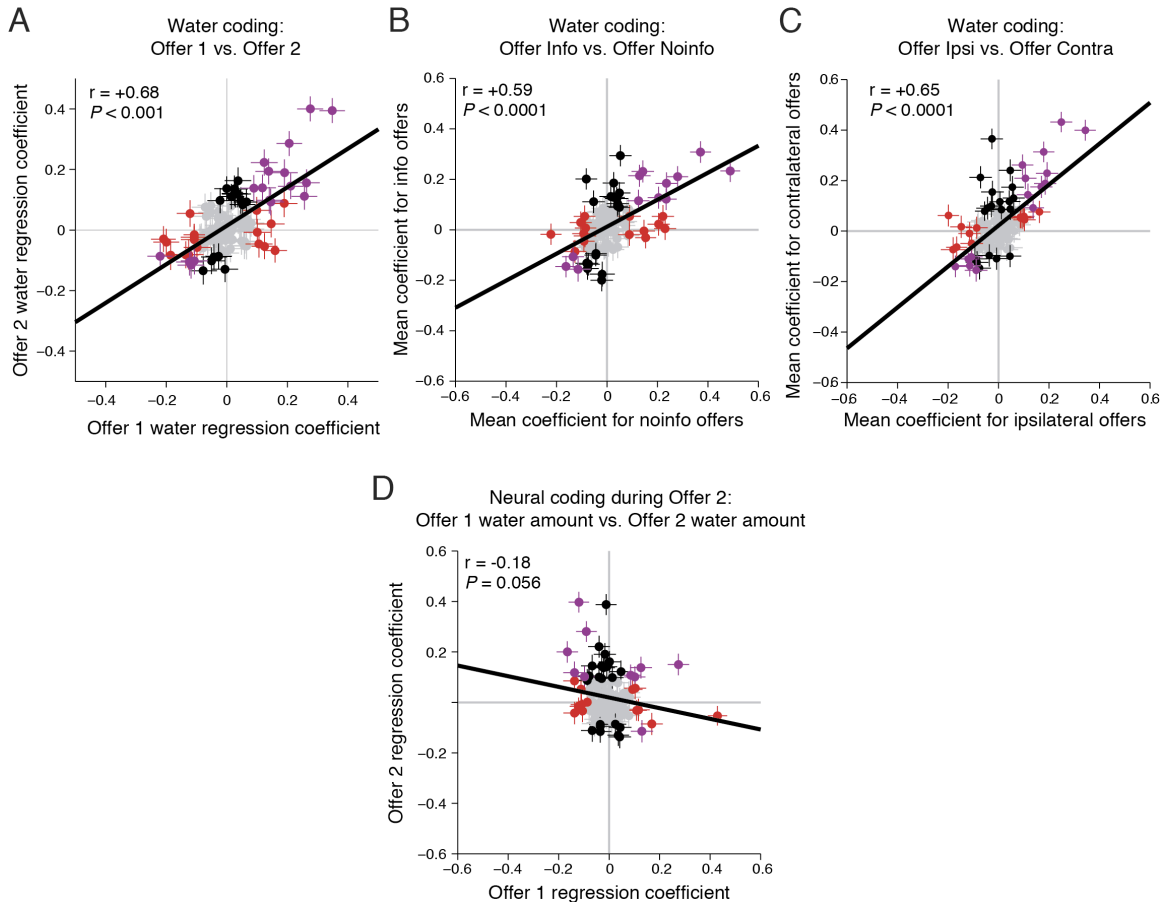
**Figure S3, related to Figure 3: Latency analysis.**

Population average signals for information (black) and water amount (red) in response to offer 1 (top) and offer 2 (bottom). Neural activity was smoothed with a causal exponential filter (mean = 15 ms). Shaded region:  $\pm 1$  SE. Solid bars at bottom of plot indicate milliseconds when the information signal (black) and water amount signal (red) were significant ( $p < 0.05$ , signed-rank test). Text indicates each signal's measured latency (defined as the first millisecond of a stretch over which the signal reached significance for at least 20 consecutive milliseconds).

Each "information signal" curve was created from the activity of the subset of neurons with a significant signals encoding the offer's informativeness (same cells that

reached significance in the main text). Each cell's information signal was measured as the difference, "firing rate in preferred informativeness condition – firing rate in non-preferred informativeness condition". Thus, cells that were either excited or inhibited by informative offers were both treated as positive information signals. The single cell signals were then averaged to get the population information signal. Each "water amount" signal curve was calculated in the same way, but comparing "high water amount" vs "low water amount" offers instead of informative vs non-informative offers.

OFC neural signals tended to have shorter latencies in response to offer 2, perhaps because the presentation of offer 1 allowed the animal to establish an expectation about the time and place where offer 2 would appear. However, in response to both offers, there was considerable overlap between neural signals for water amount and information, and they arose at similar times. This suggests that the OFC did not process these two features of offers in a specific sequential manner (e.g. signaling information first then water amount second), but rather processed them simultaneously.



**Figure S4, related to Figure 4: OFC neurons consistently coded features of the currently presented offer.**

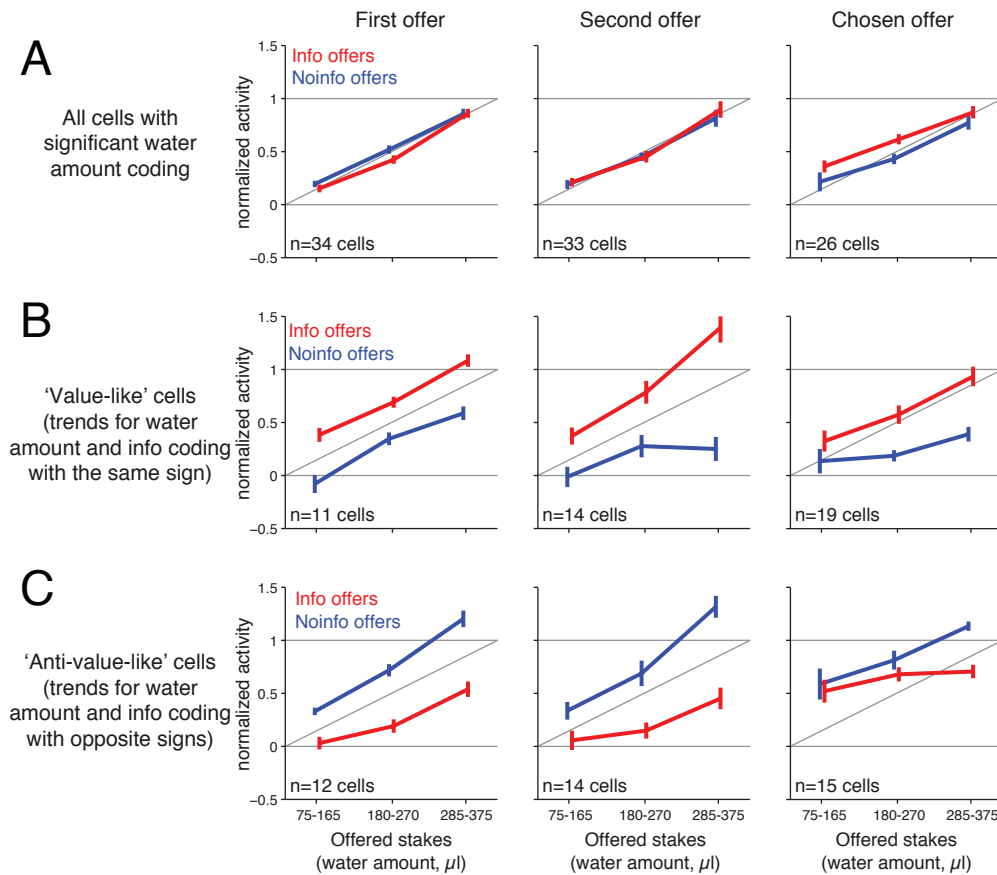
(A) Consistent neural coding of water amount for the first and second presented offers. Same as Figure 4A.

(B) Consistent neural coding of water amount for both non-informative offers (x-axis) and informative offers (y-axis). To test whether separate subpopulations of OFC neurons coded water amount for each offer type, we regressed each neuron's firing rate on offered water amount, separately for the 2x2 combinations of offer informativeness (info vs. noinfo) and offer presentation order (first vs. second). We then averaged the regression coefficients across the presentation orders to generate two indexes of the neuron's water coding, one for informative offers and one for noninformative offers. The two coding indexes were tightly correlated ( $r = +0.59$ ,  $P < 0.001$ ), indicating that neurons had consistent water amount signals for both types of offers.

(C) Consistent coding of water amount for ipsilateral and contralateral offers. Same as (B), but using offer location instead of informativeness. There was also correlated coding of informativeness for the ipsi and contra offers ( $r = +0.38$ ,  $P < 0.001$ ), similarly to the correlated coding for the first and second offers (Figure 4B).

(D) Test for influence of previously presented offer 1 on coding of the currently presented offer 2. We have reported that neurons in a closely related area, vmPFC, carry value comparison signals. These neurons encode the difference between the currently visible offer and the remembered, previously presented offer (Strait et al., 2014). We performed the analogous analysis here, regressing neural activity during the offer 2 epoch

on the water amounts from both offer 1 and offer 2. A value comparison signal would show up as a negative correlation between the regression coefficients, such that cells would use opposite signs to signal the water amounts of the current and previous offers. We find a modest trend toward negative correlation, but it did not reach significance ( $r=-0.18$ ,  $P=0.056$ ). Thus, the OFC did not predominantly encode the second offer relative to the first offer. Instead, OFC neurons represented the currently and previously presented offers in largely distinct formats.



**Figure S5, related to Figure 5. The OFC contained neurons with both value-like and anti-value-like coding of water amount and informativeness.**

Normalized activity of OFC neurons in response to the offers, as a function of water amount and informativeness. Each neuron's activity was normalized based on the best-fitting regression coefficient for its coding of water reward. Specifically, each neuron's single trial firing rates were adjusted with a constant offset and a scaling factor, so that according to the regression model the neuron's mean normalized activity would be equal to 0 for trials with the lowest offered water amount, and equal to 1 for trials with the highest offered water amount. Trials were binned based on the offer's informativeness (color: red, informative offers; blue, non-informative offers) and the offer's water reward size (x-axis: 75-165, 180-270, or 285-375  $\mu\text{L}$ ). Each data point represents the population average normalized activity in each of these conditions. Error bars are  $\pm 1$  SE.

(A) Mean normalized activity of all OFC neurons with significant coding of offered water amount for offer 1 (first column), offer 2 (second column), or the chosen offer (third column) during their respective epochs. Their normalized activity increases with water amount, but has no clear, systematic tendency to vary with informativeness as seen in behavior (see Figure S6 for a direct test of whether this activity encodes subjective value).

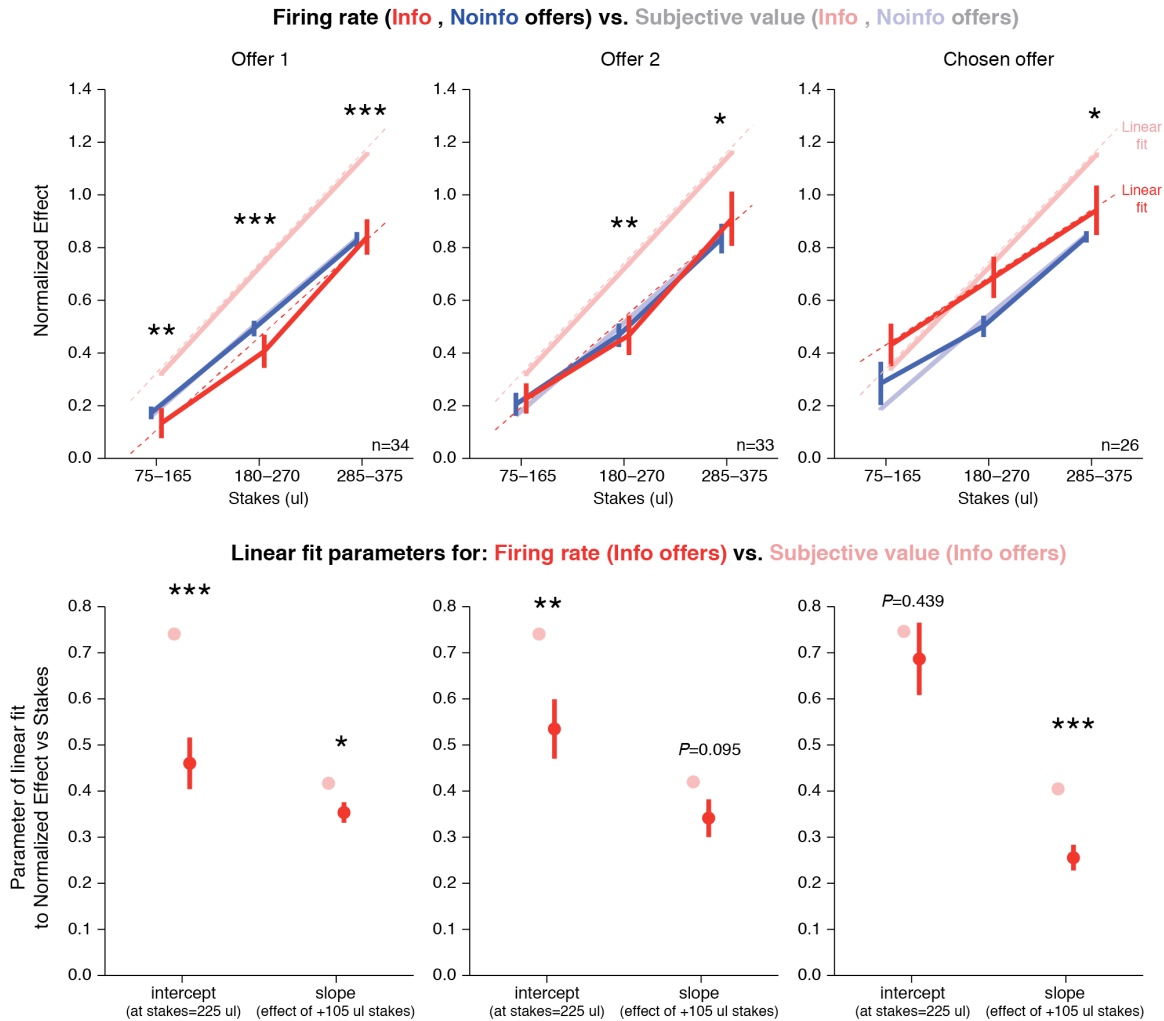
(B) Same analysis for the subset of neurons with significant trends for *value-like* coding: that is, neurons with same-sign coding of water amount and informativeness



(cells with  $P < \sqrt{0.05}$  for both effects, giving an overall false positive rate of  $\sqrt{0.05} * \sqrt{0.05} = 0.05$ ). These cells tended to code info in the same direction as water. Furthermore, they had larger difference between info vs. noinfo activity on high-stakes trials, when the monkey had a stronger behavioral preference for info (Fig. 2B).

(C) Same analysis for neurons with significant trends for *anti-value-like* coding: that is, neurons with opposite-sign coding of water amount and informativeness. These cells tended to code the *absence* of info in the same direction as water, with stronger *absence-of-info* signals on high-stakes trials.

Note that B and C have mirror image activity patterns and very similar numbers of cells. Specifically, during offer 1, 11 neurons had significant trends to encode water amount and information with the same sign, and 12 with opposite signs. During offer 2, 14 neurons used the same sign and 14 used the opposite signs. For the chosen offer, 19 used the same sign and 15 used opposite signs. Similar results were produced using a more restrictive classification criterion (cells with  $P < 0.05$  for both effects, giving an overall false positive rate of  $0.05 * 0.05 = 0.0025$ ): the number of cells with same-sign coding for the three events were 4, 5, and 7, while the number of cells with opposite-sign coding were 5, 4, and 6. Thus, the OFC did not appear to give value coding privileged status; instead, OFC neurons appeared to code water and information in all combinations, including both value-like and non-value-like combinations.



**Figure S6, related to Figure 6. Detailed comparison of neural firing rates to hypothetical value coding**

*Top:* If water-coding OFC neurons predominantly encoded subjective value, then their responses to the different offers should track the manner in which the subjective value of the offers varied with water amount and informativeness. We therefore calculated the normalized effects of offer water amount (stakes, x-axis) and offer informativeness (red vs. blue lines) on OFC responses to the offers (dark lines; estimated from neural firing rates of water-responsive neurons) and subjective value of the offers (light lines; estimated from behavior). Neural activity and subjective values were normalized based purely on data from Noinfo trials, such that the variables were 0 on Noinfo trials with the lowest stakes (75  $\mu$ L) and 1 on Noinfo trials with the highest stakes (375  $\mu$ L). This allowed us to do an independent comparison between these variables using Info trials. Info trials had high subjective value (light red lines); did they evoke high firing rates (dark red lines)?

Specifically, the analysis was done separately for the first, second, and chosen offer (left, middle, and right columns). Normalized firing rates were calculated using a similar procedure to the one used in Figure S5A, except that firing rates were normalized based purely on each cell's activity on Noinfo trials (such that the cell's estimated rate was 0 for the smallest offered water amount and 1 for the largest offered water amount;

dark blue lines). Subjective values were calculated by fitting each monkey's behavior with a GLM, such that the log odds of choosing offer 1 over offer 2 were based on the difference in subjective value between the offers, where 'subjective value' was fit as a weighted linear combination of water amount, informativeness, and their interaction. For each neuron, this provided us with an estimated subjective value for each offer on each trial. We then normalized each neuron's subjective values in the same way that we did for the firing rates (such that the subjective value was 0 for the lowest-stakes Noinfo offer and 1 for the highest-stakes Noinfo offer; light blue lines). Error bars are  $\pm 1$  SE.

The result was clear. For all three offers, there were significant differences between normalized firing rates and subjective values in response to Info offers (\*,  $P < 0.05$ ; \*\*,  $P < 0.01$ ; \*\*\*,  $P < 0.001$ ). The subjective value of Info offers was higher than Noinfo offers, and had a higher slope (light red vs. light blue). However, for both Offer 1 and Offer 2, firing rates were similar for Info and Noinfo offers (dark red vs. dark blue, left and middle columns). For the chosen offer, firing rates were slightly higher for Info offers than Noinfo offers, but did not appear to have a greater slope (right column).

*Bottom:* Direct test of value coding. We used linear regression to fit lines to the normalized firing rate (*top*, dark red dashed line) and value (*top*, light red dashed line). This summarizes the neural and behavioral responses to Info offers as a function of stakes, using two parameters, the line's intercept and slope. We then tested for significant differences in the best-fitting regression parameters for neurons (dark red) vs. behavior (light red). Error bars are  $\pm 1$  SE.

For all three offers, there were clear, significant differences between neural responses and subjective values, either in the best-fitting line's intercept (Offer 1,  $P < 0.001$ ; Offer 2,  $P < 0.005$ ) or its slope (Offer 1,  $P = 0.015$ ; Chosen offer,  $P < 0.001$ ).

## **SUPPLEMENTARY EXPERIMENTAL PROCEDURES**

***Cross validation methods.*** Some of our results rest on low levels of correlation between regression coefficients. Without further examination, these null results could be explained as being caused by a dataset with a low signal-to-noise ratio. To test this possibility, we examined a measure of the test-retest reliability of our measurements, using the correlation between regression coefficients for the same variable, but from different, non-overlapping sets of trials. For each of these analyses, we separated the data into two sets, using even numbered trials to define one set and odd numbered trials to define the other. We ran regressions on each of those sets separately, and then compared the regression coefficients coming from each of these two sets. As these regression coefficients came from the same period and the same variable, we would expect them to be perfectly correlated if there is no noise in the data, and for any deviation from this to be a measure of the noise in the data. Since we used separate, non-overlapping sets of trials, any correlation is due to true signal in the data. Thus, finding a strong positive correlation using this technique suggests that a lack of a correlation between regression coefficients for different variables was not simply due to noise in the data.

***Pairing procedure for choice period analysis.*** Regression coefficients for the epochs where the options were initially presented are straightforward to calculate, because the variables being coded are statistically independent. For example, the reward size and informativeness of the first option presented are drawn independently by the task program. Regression coefficients for the chosen offer are more difficult to calculate because ‘chosen water’ and ‘chosen info’ are negatively correlated in most sessions, due to the animal’s selection bias (i.e., animals were willing to accept offers with low water amounts if the offers gave info). Simulations demonstrated that the negative correlation between ‘chosen water’ and ‘chosen info’ tended to induce spurious correlations between the estimated regression coefficients, even if there was no correlation between the true, underlying neural water signal and info signal. To avoid this potential confound, we restricted our analysis of chosen offers to a subset of trials for each neuron selected using a matched-pair procedure, in which each choice of an informative offer was matched with a corresponding choice of a non-informative offer, such that the two trials in the matched pair had very similar chosen water amounts ( $\leq 15$  ul difference in water amount). Informative trials that could not be matched with a corresponding non-informative trial were excluded from this analysis, typically resulting in approximately 1/3 of a neuron’s trials being excluded (mean: 33%. range: 8%-68%). This procedure eliminated any correlation between ‘chosen water’ and ‘chosen info’ variables (before: mean  $r = -0.103 \pm 0.008$  (SE), after: mean  $r = +0.002 \pm 0.001$  (SE)). In simulations this successfully removed spurious correlations between the regression coefficients, while still including enough trials in the analysis to estimate the coefficients with good accuracy.

***Surgical procedures.*** All animal procedures were approved by the University Committee on Animal Resources at the University of Rochester and were designed and conducted in compliance with the Public Health Service’s Guide for the Care and Use of Animals. Two male rhesus macaques (*Macaca mulatta*) served as subjects. A small prosthesis for holding the head was used. Animals were habituated to laboratory conditions and then trained to perform oculomotor tasks for liquid reward. A Cilux recording chamber (Crist Instruments) was placed over the orbitofrontal cortex. Position

was verified by magnetic resonance imaging with the aid of a Brainsight system (Rogue Research Inc.). Animals received appropriate analgesics and antibiotics after all procedures. Throughout both behavioral and physiological recording sessions, the chamber was kept sterile with regular antibiotic washes and sealed with sterile caps.

**Recording site.** We approached OFC through a standard recording grid (Crist Instruments). We defined OFC as the coronal planes situated between 29 and 36 mm rostral to the interaural plane, the horizontal planes situated between 0 and 9 mm from the ventral surface, and lateral to the medial orbital sulcus (**Figure 1B** and **Figure S1**). These coordinates correspond to area 13m (Öngür and Price, 2000). Our recordings were made from a central region within this zone. We confirmed recording location before each recording session using our Brainsight system with structural magnetic resonance images taken before the experiment. Neuroimaging was performed at the Rochester Center for Brain Imaging, on a Siemens 3T MAGNETOM Trio Tim using 0.5 mm voxels. We confirmed recording locations by listening for characteristic sounds of white and gray matter during recording, which in all cases matched the loci indicated by the Brainsight system with an error of <1 mm in the horizontal plane and <2 mm in the z-direction.

**Electrophysiological techniques.** Single electrodes (Frederick Haer & Co., impedance range 0.8 to 4M  $\Omega$ ) were lowered using a microdrive (NAN Instruments) until waveforms of between 1 and 3 neuron(s) were isolated. Individual action potentials were isolated on a Plexon system (Plexon). Neurons were selected for study solely on the basis of the quality of isolation; we never pre-selected based on task-related response properties. All collected neurons for which we managed to obtain at least 300 trials were analyzed (although in practice, the smallest trial set was 396 trials); no neurons that surpassed our isolation criteria were excluded from analysis.

**Eye-tracking and reward delivery.** Eye position was sampled at 1000 Hz by an infrared eye-monitoring camera system (SR Research). Stimuli were controlled by a computer running Matlab (Mathworks) with Psychtoolbox (Brainard, 1997) and Eyelink Toolbox (Cornelissen et al., 2002). Visual stimuli were colored rectangles on a computer monitor placed 57 cm from the animal and centered on its eyes (**Figure 1A**). A standard solenoid valve controlled the duration of water delivery. The relationship between solenoid open time and water volume was established and confirmed before, during, and after recording.

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